No. 7

PINK BOLLWORM INFORMATION

COOPERATIVE RESEARCH ON THE PINK BOLLWORM AND RELATED COTTON INSECTS

ENTOMOLOGY RESEARCH CENTER
AGRICULTURAL RESEARCH SERVICE, U.S.D.A.
BROWNSVILLE, TEXAS

PINK BOLLWORM INFORMATION NO. 7

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This periodic circular of information giving progress of research on the pink bollworm was originally intended to appear at least twice each year. Later, it became an annual report timed to be of benefit at the annual meetings of the Pink Bollworm Technical Research Committee and the Regional Project S-37 on pink bollworm control. With the revision of Regional Project S-37 to include practically all research being done on the pink bollworm, the committee meetings were timed so as to make use of the S-37 annual reports. This latter procedure eliminated the need for the periodic reports formerly used at the meetings, but distribution of the S-37 reports was limited.

This, the seventh issue of "Pink Bollworm Information," is the only one appearing since June 1958. It contains the 1958 and 1959 Regional Project S-37 annual reports. At the last S-37 committee meeting held at College Station on October 22-23, 1959, it was agreed that these two reports should be bound in a single cover, as PINK BOLLWORM INFORMATION NO. 7, for distribution to certain interested officials who do not receive S-37 reports through the usual channels. These are brief summary reports. Anyone desiring more detailed information on a particular subject should write to the agencies reporting on the subject.

As is true with previous issues of this publication, it is 'Administratively Confidential' and must not be quoted without prior approval of the agency responsible for the particular statement concerned.

CONTENTS

Page

1959 ANNUAL REPORT

ANNUAL REPORT OF COOPERATIVE
REGIONAL PROJECT S-37
1958

1. PROJECT: S-37, Pink Bollworm Control.

2. COOPERATING AGENCIES AND PRINCIPAL LEADERS:

Arkansas Agricultural Experiment Station	- Dr. Charles Lincoln**
Louisiana Agricultural Experiment Station	- Dr. L. D. Newsom
Texas Agricultural Experiment Station	- Dr. R. D. Lewis*
	- Dr. J. C. Gaines
	- Dr. P. L. Adkisson
	- Dr. S. P. Johnson
	- Mr. L. H. Wilkes
Entomology Research Division, ARS, USDA	- Dr. S. E. Jones
	- Dr. D. F. Martin***
	- Dr. Erma S. Vanderzant
Plant Pest Control Division, USDA	- Mr. F. I. Jeffrey
State Experiment Stations Division, USDA	- Dr. E. R. McGovran

3. PROGRESS OF THE WORK AND PRINCIPAL ACCOMPLISHMENTS:

Biology, Ecology, and Biological Control

Studies of Larval Diapause

Studies continued for the third year at Waco showed that the percentage of larvae entering the resting stage increased as the season progressed, and the percentage was higher in bolls than in squares. Diapause larvae occurred in all generations that developed in bolls, with up to 11% of the population going into diapause during July and August with a rapid increase beginning September and rising to 93% or more in October and November. This data indicates the need of harvesting the crop as early as possible and the subsequent destruction of stalks to reduce breeding and increase of the long-cycle larvae.

Results of studies in bioclimatic cabinets at Brownsville showed the percentage of larvae entering diapause was influenced by day-length and quality of light. When exposed to 16-hour days during the

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* Administrative Adviser
** Chairman, Technical Committee
*** Secretary, Technical Committee

developmental period, approximately 60% of the larvae entered diapause compared with 95% for a 10-hour day under the same conditions of temperature and humidity. There was no difference in effect between constant temperature and fluctuating temperature simulating natural day and night fluctuations. In other experiments, the percentage of larvae entering diapause increased when light in the red region of the spectum was increased. Also, it was found that larvae developing on plants growing in a greenhouse had a higher percentage enter the resting stage than those that developed under similar temperature in outdoor cages.

Preliminary data obtained at College Station indicated that oil content of the diet, humidity, and temperature may affect the percentage of laboratory-reared larvae entering diapause.

A knowledge of the factors influencing diapause is important because it might lead to ways of preventing it or ways of breaking it and leading to suicidal emergence of the moths. Data obtained in laboratory tests indicate that mechanical disturbance such as ginning had some effect on the time of moth emergence in the spring. The peak of emergence from ginned seed was on March 29. Emergence from unginned seed showed two peaks -- March 29 and May 3. Although optimum temperature and moisture conditions for pupation were maintained from the beginning of these tests on January 22, it is interesting to note that the main portion of the emergence occurred at the same time as that in outdoor cages at Brownsville, namely between March 15 and April 15.

Parasites and Predators

A small shipment of Bracon greeni, imported from India, was received through the Parasite Introduction Laboratory, Moorestown, New Jersey. This parasite had not been released in this country but previous attempts had been made to rear it for release. Part of the recent shipment was used in further unsuccessful efforts to develop a rearing technique. The remainder was introduced into a large screen cage with pink bollworm-infested cotton; however, boll collections failed to show the development of a new generation.

Pathogenic Organisms

Nematode DD-136 with its associated bacterium was ineffective against the pink bollworm and boll weevil in small-plot field test. The pathogen was applied on the cotton plants weekly from June 6 to July 11 at a rate of approximately 10,000,000 nematodes per acre each week. Weekly infestation counts showed no differences between treated and untreated plots. Bioassay tests with soil samples taken 65 days after application of the nematode indicated that it did not survive this period in the soil.

This project has been handicapped by the failure, as yet, to find a qualified insect pathologist to fill the position left vacant in the fall of 1957.

Physiology, Nutrition, Biochemistry, and Morphology

The Effects of High Temperature on Adult Pink Bollworm Mortality

The age of the individual adults is very important as the mortality varies inversely with the age, as determined in studies at Brownsville. Differences in humidity are important as the moths were killed with less heat when the humidity was high. Temperatures of 115° F. or higher caused immediate heat rigor and subsequent somatic injury resulting in paralysis, the extent of which varied inversely with the amount of applied heat. The moths recovering from this paralytic state were very inactive for the rest of their lives. Temperatures above 131° F. for 2 minutes caused 100% mortality.

Respiratory Studies of the Pink Bollworm

Results of the respiratory measurement of various stages of the pink bollworm showed an average oxygen uptake of 2.3 $mm^3/hr/mg$ at 82° F. at Brownsville. The oxygen consumption of the eggs and fourth-instar nondiapause larvae was the highest. There was a consumption factor of 26x between the nondiapause and diapause fourth-instar larvae. There was only a difference of 0.02 $mm^3/hr/mg$ oxygen uptake between the diapause larvae without cocoons and those in cocoons. There were no differences in the rate between the sexes. The low oxygen consumption of the diapause larvae is indicative of their quiescent state and is undoubtedly the reason for their ability to survive adverse conditions such as winter temperatures or being submerged in water or under soggy soil for short periods of time.

Observations of the Pink Bollworm in Soil

Observations have been made on 259 pupae buried at depths ranging from $\frac{1}{2}$" to 8" in eight soil types from medium sand to heavy clay loam held at various moisture levels in glass-walled observation boxes at Brownsville. Only 12 moths reached the surface. Most of the moths that did escape were in a weakened condition. No moths reached the soil surface if a crust due to irrigation was present.

Comparative Amino Acid, Carbohydrate, Weight, Fat, and Water Analyses

It was found that the larvae contain 27 free amino acids in their haemolymph in studies at Brownsville. The differences between diapause and nondiapause larvae amounted to four amino acids, the nondiapause larvae having taurine while the diapause larvae had o-amino-n-butyric acid, glucosamine and fast alanine. Glucose and fructose were found in about equal amounts in the haemolymph of both types of larvae. The weight, water, and lipid analyses yielded valuable information. First, the diapause 3-month-old larvae were the heaviest and contained the most water and lipids. Second, the difference between the square- and hard, green boll-fed larvae was quite obvious in weight, water,

and lipid content. Third, within the diapause larval group the fat content decreased with age until the larvae were 33 months old (stored at 50° F. to 60° F.) when the fat reserves were exhausted, at which time the larvae died.

Physiological and Autoecological Studies of the Effects Of Soil Type and Condition on the Pink Bollworm Larvae and Pupae

A comparison of three soil types in combination with certain adverse moisture and temperature conditions showed that sandy loam had the least detrimental effect on the larvae at Brownsville. Mortality was highest in sand, then clay soil, and finally sandy loam. Consistently high temperature was detrimental. Under conditions of high soil moisture, the mortality rate varied directly with the temperature, and inversely with time; i.e., there was 100% mortality in 2 days at 100° F., whereas it took 6 days at 84° F. Moist soils deterred the movements of the larvae and cocoon spinning. The results to date indicate that moisture is the major factor in the death of the larvae and pupae, especially in conjunction with higher temperatures. At 84° F. the following observations on active larvae buried under various soil conditions were noted: Cocoons protected the active nondiapaused larvae for at least 5 days; the larval mortality in dry soils reached 50% in approximately 7 days in sand and 8 days in heavy clay; the larval mortality in moist soils at approximately saturation reached 50% in approximately 2 days in both sand and heavy clay; in dry soils 50% of the larvae reached the surface in 3 days, whereas in moist saturated soils the 50% level was not reached in 9 days; and finally, certain of the data obtained from sandy loam were inconsistent and without an apparent pattern.

Nutritional Studies

The amino acid medium developed in 1956 was used in a sterile diet for the determination of the nutritive value of the D-amino acids by substituting them for the L-amino acids in studies at College Station by the Entomology Research Division. A few larvae developed and became adults when D-histidine, D-methionine, and D-phenylalanine were fed, but growth was slow and the pupae were small. D-tryptophan supported slow growth to the third-instar larvae. D-isoleucine, D-leucine, D-threonine, and D-valine could not be metabolized by the pink bollworm.

Nine successive generations reared on a sterile, chemically defined diet were similar to field populations. Moths laid about 175 eggs per female and there was no apparent decrease in number of eggs laid by successive generations. The average larval period was 16 days in an incubator at approximately 85° F. Female pupae averaged about 20 milligrams in weight, but there was a slight decrease in weights of males from the first to ninth generation.

Efforts to develop methods for mass-rearing the pink bollworm on artificial media have encountered difficulty due to contamination by molds. It was found that the addition of the antifungal agents,

sorbic acid, sodium benzoate, and n-butyl-p-hydroxybenzoate to the previously reported artificial media (basically cottonseed meal or peanut flour) controlled fungus for periods up to 60 days.

The methyl and butyl esters of parahydrozybenzoic acid, sorbic acid, and sodium benzoate were tested for their toxicity to larvae and for antimicrobial activity in a chemically defined diet, using aseptic and nonaseptic procedures. Microbial growth in the media, generally, was held to a low level. Variability in egg hatch and the drying of media precludes positive statements with respect to larval toxicity.

Considerable progress in developing mass rearing techniques has been made by workers at Texas Agricultural Experiment Station.

Physical, Mechanical, and Cultural Control Practices and Equipment

An ensilage harvester used for stalk destruction gave kills of more than 90% of the pink bollworm larvae left in the field after harvest. This machine destroyed a greater percentage of green bolls than did conventional rotary shredders. It also killed a higher percentage of pink bollworms in green bolls. These studies were cooperative between Texas Agricultural Experiment Station and Entomology Research Division.

Two makes of ensilage harvesters were operated by Plant Pest Control Division in eradication work in Arkansas. Efficiency of these machines in picking up and shredding cotton field trash after frost was studied by Arkansas Agricultural Experiment Station workers.

Effects of Soil Type and Burial Depth on Pink Bollworm Survival

Survival and emergence of pink bollworms from infested bolls buried 4" in clay soil at Brownsville was more than two times greater than in a sandy soil. In tests using clay soil with infested bolls buired 2", 4", 6", and 8", survival decreased with depth of burial. The number of moths emerging from the respective depths was 1,463, 903, 621, and 316. The larvae in all these treatments had overwintered in the bolls which were held in cool storage until buried in the spring, indicating that debris should be plowed under as deeply as possible. Spring and summer moth emergence from bolls buried in the fall at Waco, Tex., was about four times greater for 2" burial than 6" burial.

Winter Survival Studies

A 5-year study, completed in 1957, to determine winter survival of the pink bollworm under conditions of four different cultural practices simulated in cage experiments at seven localities in Texas and one in Oklahoma has been previously reported. Other studies were

continued at Waco, Mount Pleasant, and Lubbock, Tex., Chickasha, Okla., and at a new location, Heavener, Okla.

In a small-plot experiment at Waco there was no significant difference in survival between fall and winter plow-under treatments; however, the data indicate that fall or early winter plowing, disking, or listing reduce winter survival as compared with no fall or winter treatment.

A study of the time of adult emergence from overwintered pink bollworms in relation to planting date at Waco showed that the survival of moths to infest cotton decreased with delay in planting. It was found that cotton planted during the periods April 1-3, April 23-24, May 7-10, May 12-13, and May 28 began to produce squares on May 26, May 29, June 4, June 9, and June 23 respectively. Based on moth emergence records, it was therefore apparent that the number of moths infesting squares formed on these respective dates represented approximately 34, 22, 12, 9, and 5 percent of the population that survived the winter. An average of the data obtained over a 3-year period to date at Mount Pleasant, Tex., indicates that winter cover crops had little, if any, effect on winter survival of the pink bollworm.

Light Traps

The number of moths caught in a light trap operated at Waco gave an indication of the seasonal abundance of the adult population. The number caught during the respective months from April through August were 2, 11, 29, 6, and 915. Operation of the trap during part of September showed a great increase over the August catch.

In cooperation with the Plant Pest Control Division and the Agricultural Engineering Division, light traps along with other methods of detection were used to detect the pink bollworm in Arizona where attempts are being made to eradicate a new infestation. The light traps caught moths in outlying areas before any infestation was detected by other methods.

Chemical Controls and Their Correlation with Control of Other Cotton Insect Pests

The new materials, Sevin and mixtures of Guthion and DDT, are highly effective but more expensive than DDT. Sevin, tested in the field for the first time in 1957 and used in large-scale demonstrations in 1958, is more effective than DDT applied at the same rate. This material is relatively safe to handle. Guthion is extremely hazardous to handle. DDT is currently the only insecticide in general use for pink bollworm control and continues to be the most economical.

Dust applications of Sevin beginning when approximately 55% of the bolls were infested by pink bollworms and ending when 25%, 50%,

and 75% respectively of the bolls were open did not increase yields over the untreated check. However, Sevin was effective in lowering the pink bollworm population considerably below that recorded for the check in an experiment conducted by Texas Agricultural Experiment Station.

Spray nozzle arrangements of one or two conventional cone spray nozzles per row proved to be more effective for cotton insect control than single wide swath jet-type nozzles spraying 6 or 12 row swaths in experiments conducted by Texas Agricultural Experiment Station.

Timing experiments for control of boll weevil and other insects were continued in southwestern Arkansas. Again the lightest schedule (weekly applications at 40% punctures) was the most profitable. The narrow margin of profit from insecticidal control of boll weevil means that added costs for insecticidal control of the pink bollworm could not be borne with present yields and production practices.

Laboratory Tests

Laboratory tests were continued at Brownsville in an effort to find new promising materials for pink bollworm control. Of 29 compounds tested, 7 were more effective than DDT against pink bollworm adults. These compounds were American Cyanamid 12880; Shell BAS-4092, SD-4402, SD-2244, SD-3562; and Cal. Spray ML-97.

With the thought that possibly a synergistic effect might be obtained from different combinations of the commonly used insecticides, comparative tests were done with combinations of DDT-dieldrin (3:1) and DDT-Guthion (3:1) applied against the pink bollworm. No synergistic or additive effect was evidenced.

Chemicals that are highly attractive to pink bollworm adults are needed for use in detecting incipient infestations, measuring abundance of the insect in the generally infested area and possibly increasing the effectiveness of insecticide applications. One hundred forty-three compounds were tested for attractiveness to the pink bollworm. The m-isopropoxybenzyl ester of chrysanthemumic acid was found to have greater attractancy than the cotton boll and has been adopted for use as a standard for evaluating other materials. Several other chemicals related to the standard have shown attractiveness about equal to the standard.

To determine their potential for developing resistance to insecticides, pink bollworms are being reared on larval medias containing DDT and Guthion at Texas Agricultural Experiment Station and after four generations exposure to DDT and three to Guthion, no evidence of increased insecticide resistance has been found.

Host Plants and Resistance or Tolerance

A Gossypium hirsutum x G. tomentosum cross exhibited antibiotic properties to pink bollworm larvae. A backcross of the cotton to its G. hirsutum parent showed no evidence of antibiotic properties to the larvae but did inhibit egg production of the resulting female moths.

Pubescent was one of the least preferred varieties for oviposition of the females in work at Texas Agricultural Experiment Station.

Nectarless Cotton Variety

Previous preliminary tests have indicated that a nectarless variety limited pink bollworm population build-up, presumably due to lack of food for the moths. Similar experiments were repeated with the pink bollworm, cotton leafworm, and cabbage looper. The variety called "nectarless" used in these tests actually had functional nectaries on approximately 5% of the leaves and fruiting forms. Infestation records indicated that this limited amount of nectar did not influence pink bollworm increase but did greatly reduce the increase of cotton leafworms and cabbage loopers. The first generation of cabbage looper larvae and pupae, counted on one row in each cage, was 22 on the nectarless cotton and 238 on the check. Cotton leafworms on 10 plants in each cage were 238 and 444 for the respective varieties. Visible difference in leaf damage on the plants was readily evident.

Several plants and lines exhibiting resistance to boll weevil were selected at Arkansas Agricultural Experiment Station. Types of resistance include tolerance, nonattractiveness, and probably antibiosis. Included in the resistant material are commercial types, as well as red, hairy, cluster, and cup-frego.

Secondary Host Plants

Only one species, Gleditsia triacanthos L. (honey locust) was discovered during the past year, making a total of 38 known host plants found in the infested area. Should further spread of the insect occur, search for host plants and studies of their importance in the new area would be warranted.

Lint and Seed Quality

In insecticide experiments conducted in 1957 at Brownsville, the pink bollworm greatly reduced the quality and yield of cotton on untreated check plots. The check produced 150 pounds of seed cotton per acre compared with 1,260 for the most effective treatment, a gain of 1,110 pounds primarily due to pink bollworm control. Seed cotton samples taken from the grower's harvest were ginned and the lint classed. Lint from the heavily infested check plots graded "Low Middling Spotted, 1-1/16-inch staple," valued at 21.71 cents per pound; whereas, lint from the lightly infested plots graded "Strict

Low Middling Plus, 1-3/32-inch staple" with a value of 32.66 cents per pound, based on 1958 prices.

Experiments were conducted in large screen cages to determine the effects of various degrees of pink bollworm infestation, ranging from low to high, which were obtained by introducing various initial populations. Other tests were made in which infestation with various numbers of larvae per boll were obtained by introducing various initial populations. Other tests were made in which infestation with various numbers of larvae per boll were obtained by placing known numbers of eggs on tagged bolls. Samples were obtained from the cotton produced under these conditions but have not as yet been analyzed. The lint will be classed as to grade and fiber length, strength, fineness, and maturity.

4. USEFULNESS OF FINDINGS:

Information obtained in ecological studies has been valuable in developing cultural practices that are effective in reducing pink bollworm populations. Regulations on compulsory stalk destruction and time of planting are based on this work. Biochemical studies helped in work toward developing techniques for rearing insects for experimental purposes.

Cultural practices for pink bollworm control have proved highly effective and beneficial. Regulated planting and stalk destruction dates greatly reduce infestations of both the pink bollworm and boll weevil in the Lower Rio Grande Valley. The use of stalk shredders that kill a high percentage of the potential overwintering pink bollworms have been readily accepted by cotton growers. Studies of mechanical kill at the gin and oil mill have brought about the abolition or revision of certain quarantine requirements resulting in annual savings to the cotton industry amounting to well over three million dollars in Texas and New Mexico. Light traps have been used to detect new infestations, thereby aiding in prompt activation of an eradication program in Arizona during 1958.

It has been possible to recommend two new chemicals, Sevin and Guthion, for use against the pink bollworm, as a result of research conducted during the year. Formerly, only DDT was recommended. With the new addition, the grower has three chemicals with different modes of action for use in pink bollworm control. Also, in laboratory experiments several new compounds showed sufficient promise to warrent field testing. Currently recommended spray nozzle arrangements proved to be the most effective.

Resistant varieties would be particularly useful on pink bollworm, because of the expense and limited effectiveness of insecticidal promise of control of cotton leafworm and cabbage looper. Other sources of resistance to pink bollworm and boll weevil are being explored and offer promise.

5. WORK PLANNED FOR NEXT YEAR:

The project outline has been revised by the Technical Committee for submission to the Committee of Nine in March 1959. This revision is to be under the title "Basic Factors Involved in the Control of the Pink Bollworm," and will provide for the full and effective cooperation of state and federal agencies on all fundamental phases of research relating to pink bollworm.

Detailed ecological records of the interrelationship of soil and air temperatures, rainfall, and soil moisture on the pink bollworm will be made in field experiments. Bioclimatic cabinets and constant-temperature cabinets located at Brownsville will be utilized to study effects of temperature and moisture on survival and activity. Effects of light, moisture, maturity of the plant and other factors on diapause will also be determined by use of this equipment and greenhouse.

There will be greater emphasis on the use of pathogenic organisms for pink bollworm control. Factors influencing effectiveness of pathogens are to be determined.

Physiological, biochemical and morphological studies will be continued in efforts to find a weak point in pink bollworm make-up for exploitation in control. Efforts will be made to improve mass-rearing methods to facilitate the use of insects of known ages and histories in much of this work, particularly in metabolic studies.

Continuation of experiments to determine winter mortality of the pink bollworm under conditions of various cultural practices at several localities are planned. Some of the commercial stalk shredders will be evaluated for killing pink bollworms. In cooperation with the Agricultural Engineering Research Division, work with light traps will involve their usefulness in determining insect abundance, detecting incipient infestations, and in ecological studies.

New insecticides will be tested against the pink bollworm in the laboratory. Those having shown promise in the laboratory will be used in field tests. Field tests will be conducted to obtain further information on timing of applications. Chemicals will also be tested as attractants for the adult pink bollworm. Research on spray nozzles will be continued.

Work will be continued on resistant varieties.

Studies on effects of various levels of infestation on yield and quality will be continued. Cotton from treated and untreated plots in insecticide experiments will be ginned and samples analyzed to determine the effects of pink bollworm infestation on the quality of lint.

6. PUBLICATIONS ISSUED OR MANUSCRIPTS PREPARED DURING THE YEAR:

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Clark, Edgar W. 1958. A literature review of calcium and magnesium in insects. Ann. Ent. Soc. Amer. 51(2):142-54.

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Chapman, A. J., L. W. Noble, O. T. Robertson, and L. C. Fife. Survival of the pink bollworm under various cultural and climatic conditions.

Clark, Edgar W. A comparative study of the amino acids, fats, carbohydrates and water of nondiapause and diapause pink bollworm larvae. Read at ESA Southwest Branch Meeting, Houston, Tex., Feb. 10-11, 1958.

Clark, E. W., A. L. Williamson, and C. A. Richmond. An improved Berlese funnel apparatus and laboratory technique for collecting pink bollworm and other insect larvae.

Martin, Dial F. Cotton insect control north and south of the border. Read at American Congress Meeting, Brownsville, Tex., June 6, 1958.

Richmond, C. A. and R. L. McGarr. Field tests with Sevin against cotton insects in the Lower Rio Grande Valley, 1957. Read at ESA Southwest Branch Meeting, Houston, Tex., Feb. 10-11, 1958.

Robertson, O. T., V. L. Stedronsky, and D. H. Currie. Kill of pink bollworms in cotton gins and oil mills.

Shiller, Ivan. The effect of burial depths on the emergence of pink bollworm in cotton crop residues. Read at ESA Southwest Branch Meeting, Houston, Tex., Feb. 10-11, 1958.

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7. APPROVED:

/S/ Charles Lincoln	/S/ R. D. Lewis
Chairman, Technical Committee	Regional Administrative Advisor

1959
ANNUAL REPORT OF COOPERATIVE
REGIONAL PROJECT S-37

1. PROJECT: S-37, Basic Factors Involved in the Control of the Pink Bollworm

2. COOPERATING AGENCIES AND PRINCIPAL LEADERS:

Arkansas Agricultural Experiment Station	- Charles Lincoln**
	- Robert C. Hunter
Louisiana Agricultural Experiment Station	- L. D. Newsom
Texas Agricultural Experiment Station	- R. D. Lewis*
	- J. C. Gaines
	- P. L. Adkisson
	- L. H. Wilkes
Entomology Research Division, ARS, USDA	- S. E. Jones
	- D. F. Martin***
	- A. J. Chapman
	- L. W. Noble
	- E. W. Clark
	- H. M. Graham
	- C. M. Ignoffo
	- M. J. Lukefahr
	- M. T. Ouye
	- H. M. Taft
Crops Research Division, ARS, USDA	- W. H. Tharp
	- T. R. Richmond
Agricultural Engineering Research Division, ARS, USDA	- J. P. Hollingsworth
Plant Pest Control Division, ARS, USDA	- F. I. Jeffrey
State Experiment Stations Division, USDA	- E. R. McGovran

3. PROGRESS OF THE WORK AND PRINCIPAL ACCOMPLISHMENTS:

OBJECTIVE 1: To investigate the biology, ecology and biological control of the pink bollworm.

Studies of Larval Diapause: Temperature, photoperiod, oil content and dryness of the larval food were found to be factors in the percentage of larvae entering diapause. Low temperature, short days and long nights, high oil food and dry food were all important factors in

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* Administrative Advisor
** Chairman, Technical Committee
*** Secretary, Technical Committee

increasing the number of larvae to enter diapause. Of the factors studied, temperature appeared to have the most significant influence. Different results were obtained under the same rearing conditions when larvae were reared on diets composed of different constituents. (TAES)

Gradually decreasing day-lengths from 16 to 12 hours was conducive to larval diapause, whereas the reverse in day-length resulted in decreasing the percentage of diapausing larvae. There was an indication that the effect was through the plant. Age of the boll appeared to have some influence. (ENT, ARS)

Cold Tolerance Tests: Up to 50% of long-cycle larvae were killed in 1 to 8 hours when exposed to 10° F. in the laboratory. The tests indicated that survival was influenced by age of the larvae and temperature conditions prior to exposure to the low temperature. (ENT, ARS)

Effects of Weather on Winter Survival: The unusually low pink bollworm survival in hibernation experiments at the various locations was attributed to severe cold weather and heavy rains. (ENT, ARS)

Seasonal Activity Studies: The number of moths caught monthly in an argon light trap exposed in a field in the Lower Rio Grande Valley starting in April were: May, 3; June, 1; July, 93; August, 6,259; September, 1,801. None were taken before May 30. (ENT, ARS)

Parasites and Pathogens: Two species of parasites were introduced from Hawaii but not established in the field. Nematode DD-136 and its associated pathogen had little influence on winter survival of pink bollworm in bolls that were treated with a nematode suspension and buried in December. Weekly applications of *Bacillus thuringiensis* sprayed at 4 pounds per acre resulted in only slight reduction in the pink bollworm infestation. (ENT, ARS)

OBJECTIVE 2: To investigate the physiology, nutrition, biochemistry and morphology of the pink bollworm.

Gamma Irradiation: Incomplete initial studies on irradiation of various stages of the pink bollworm indicate that moths receiving 35 Kr or less laid eggs, but the number and hatchability was decreased. Moths from pupae receiving less than 9 Kr and moths from larvae receiving 2.5 Kr laid fertile, hatchable eggs. The longevity of moths receiving 120 Kr was reduced 45%. The mortality rate of pupae exposed to 18.5 Kr or less was at most 10%, and moths from the surviving pupae had a normal life span. The lethal dose at which death occurred in the pupal stage was 10 Kr for nondiapause larvae and 15 Kr for diapause larvae. The dose required to kill the larvae immediately was between 50 Kr and 120 Kr. (ENT, ARS)

Terrestrial Factors: In studies to determine cause of winter mortality, high soil moisture appeared to be the major factor. Soil

type and temperature were contributing causes. Diapause larvae had the same but slower reactions as nondiapause larvae. (ENT, ARS)

Effects of Integumental Abrasion and Submersion: When 2- to 3-month-old diapause larvae were submerged in water at 48° F., it took 24 days to obtain 100% mortality with an LT_{50} of 14 days (time required for a 50% kill). Nondiapause larvae lightly abraded with fine emery cloth absorbed up to 10 times as much water as unabraded larvae when immersed under water for 24 or 48 hours at 84° F. Abraded larvae lost up to twice as much water as unabraded larvae when held under dry conditions. Larvae crawling through sandy soil became scratched on the anterior edge of the first thoracic segment. Such abrasion may result in increased mortality under field conditions. (ENT, ARS)

Nutritional and Mass Rearing Studies: Of diets studied, the wheat germ diet appeared to be the most satisfactory for general laboratory rearing. The average size of insect and length of developmental period on this diet were comparable to those reported for the insect in the field. (TAES)

Three main difficulties in mass rearing have been cannibalism, a tendency of newly hatched larvae to leave the media, and mold contamination of the media. Sterile scraps of paper, cloth, absorbent cotton, or folded paper incorporated with the medium show some promise as physical barriers to separate the larvae. No satisfactory method for confining newly hatched larvae has been found. Molds were controlled with 0.2% methyl paraben or sorbic acid without appreciably affecting larval development. (ENT, ARS)

OBJECTIVE 3: To evaluate physical, mechanical and cultural control practices and equipment.

Light Traps: In light trap studies, pink bollworm moths showed the greatest response to wavelengths in the green region of the spectrum in the vicinity of 515 Mu. Moth response increased with intensity at all wavelengths tested. There was no detectable difference in response between vertically and horizontally polarized radiation at 515 Mu. Response to ultraviolet source pulsed at 180 cycles/minute decreased under that for constant radiation. The $\frac{1}{4}$-inch mesh screen, used to keep out large insects, reduced catches of insects in general by 76% and moths comparable in size to the pink bollworm moth by 45% in traps at College Station. The respective insects were reduced 74% and 21% in an argon survey trap. A 4' x 8' windbreak resulted in increasing the catches by 28% for insects in general and 42% for the pink bollworm. Operation of a blacklight fluorescent lamp in competition with a tungsten lamp at a distance of 10 feet resulted in decreasing the catches in the tungsten-equipped trap. This competition decreased with distance between lamps up to 200 feet. (AE, ARS)

Pink bollworm moths were attracted to light intensities produced by three 2-watt G.E. AR-1 argon bulbs located at distances up to 200 feet away. Moth catches were higher in a trap shielded from the prevailing wind. There was a slight decrease in number of pink bollworm moths caught in traps fitted with $\frac{1}{4}$-inch hardware cloth. (ENT, ARS)

Stalk Shredders: Nearly 90% of the pink bollworm larvae left in the field after harvest were killed when stalks were shredded with the flail rotary chopper or the utility crop chopper. The conventional rotary shredder produced significantly less kill. (TAES)

Cultural Control: In Arkansas, agronomists are conducting research aimed at developing a "scheme" of cotton production for areas of low and medium yield potential. This scheme involves short-season, determinate, stripper-type varieties; community-wide, probably late, planting date; soil management and cultural practices for such a system. Entomological work is arrived at through developing the best and cheapest insect control program for the system and predicting the effect of such a system on the pink bollworm. If such a system were put into practice, a very unfavorable environment for the pink bollworm would be created. (AAES)

At College Station, plowing tests indicated that reductions of approximately 75% of the field population of pink bollworms can be obtained by winter plowing. There was no significant difference between moldboard and lister type plows in this respect. (TAES)

Flat-breaking with a moldboard plow to a maximum depth of 6 inches in November followed by late winter listing was significantly better in reducing pink bollworm survival than four other cultural practices used in central Texas. Listing in November was significantly better than listing in February. Moth emergence was delayed in the spring where oats was used as a cover crop, whereas emergence was earlier where the land was plowed in the fall. The highest survival occurred in bolls remaining on the soil surface throughout the winter in experiments at Waco, Mount Pleasant, and Lubbock, Tex., Chickasha and Heavener, Okla. The earlier the burial of bolls, the lower was the survival at Waco, Mount Pleasant, and Heavener. Survival was too low at Lubbock and Chickasha for a reliable comparison between treatments. Based on a 3-year study at Mount Pleasant, survival in bolls held on the soil surface until buried was lower for November and February burials than March and April burials. The lowest survival was from November burial. Fall-planted cover crops had little effect on pink bollworm survival in bolls exposed on the soil surface until buried in November, February, and March in a 4-year study at Mount Pleasant. In experiments covering 3-5 years, there was little difference in rate of survival among dates of burial and dates of spring irrigation at Lubbock. At Checkasha, over a 5-year period, the difference in survival between fall and winter burial was negligible. Survival of larvae in bolls on the soil surface which were buried in March was greater than that for fall burial. Based on moth emergence records, the percentage of moths

surviving to infest squares decreased from 65% for cotton planted April 1 to less than 2% for June 9 planting at Waco. However, the later plantings were too late for maximum crop production. (ENT, ARS)

OBJECTIVE 4: To develop effective chemical controls and to coordinate these with the control of other cotton insect pests.

Field Experiments: Tests with spray nozzles ranging from 3x to 18x indicated better cotton insect control with the nozzles (3x and 6x) that produce the smaller droplet sizes. Granular insecticides applied to the soil early in the spring were not effective in reducing pink bollworm moth emergence. (TAES)

One or two applications for overwintered boll weevils gave good suppression, contrasting with 1958 results, in tests conducted in Arkansas on 1-acre plots of three timing schedules on late-planted cotton. (AAES)

Insecticide applications begun on July 9 did not increase cotton yield over that for applications begun 1 to 2 weeks later, under conditions of relatively low pink bollworm infestation at Brownsville. Sevin and endrin were more effective against the pink bollworm when applied as foliage sprays than when applied as granules. Of three new insecticides tested in the field, none showed promise for pink bollworm control. Under conditions of heavy infestation, pink bollworm eggs, mines, and larvae were reduced 20%, 68%, and 72%, respectively, when DDT was applied weekly at 2.5 pounds per acre. Seven times more larvae entered the fruiting forms of untreated as compared to treated plants when eggs were placed on terminals of plants. When eggs were placed on treated and untreated bolls, larval entrance was reduced 71% and 12%, respectively. Five new systemic insecticides applied as side dressing at rates of 5 and 10 pounds per acre were ineffective in controlling pink bollworm and boll weevil larvae. (ENT, ARS)

Laboratory Tests: Of 49 new experimental compounds tested, only 3, Shell 5533, 5539, and Velsicol 53-CS-17, warranted further investigation. The new Sevin 85% sprayable formulation appeared to be as effective as the dust formulation. Apparent synergistic action between DDT and its fluorine analog, 2,2-difluor-1,1-bis(p-chlorophenyl)ethanol, was demonstrated against the salt-marsh caterpillar; however, there was no synergism indicated when the materials were applied against the pink bollworm, boll weevil, and cotton leafworm. Of 250 new materials tested for attractiveness to pink bollworm adults, only 1, an ether extract of fresh grass (Festuca sp.) showed promise. (ENT, ARS)

OBJECTIVE 5: To evaluate cotton types for resistance or tolerance.

Preliminary results indicate that plants of Gossypium hirsutum race marie galante possess a high degree of resistance to pink bollworm attack. This resistance appears to be due to proliferation of tissue

of the carpel wall surrounding the larval entrance holes. Progeny of crosses of this species with Deltapine 15 appears to possess similar characters of resistance. (TAES and CR, ARS)

Pink bollworm populations were lower on experimental nectariless cottons than DPL-15 in tests conducted on randomized small plots isolated by barriers of tall sorghum grown between the plots. The nectariless varieties had fewer mines and larvae per gram of boll weight than DPL, indicating that larval food was not a factor limiting the population levels. Populations of bollworm, cotton leafworm, and cabbage looper were only slightly affected by the nectariless cottons in these tests. Two new pink bollworm host plants (Abutilon hirtum Sweet and Hibiscus incanus Wendl.) were found, making a total of 40 known host plants found in the infested area. (ENT and CR, ARS)

OBJECTIVE 6: To evaluate effects of pink bollworm infestations on quality of lint and seed.

Quality and yield tests indicate that heavy pink bollworm infestations can reduce the yield of cotton grown on productive soil under conditions of high moisture. (TAES)

In studies of quality and yield loss from pink bollworm damage, percentage losses in total crop value (yield and quality) per acre were 6%, 9%, and 37% for light, medium, and heavy infestations, respectively. In other experiments utilizing tagged bolls infested by hand, the quality of lint decreased as the number of larvae per boll increased. This was also true of lint ginned from seed cotton from a 50:50 mixture of infested and noninfested bolls. (ENT, ARS)

4. USEFULNESS OF FINDINGS

Reports of work on stalk shredders and spray nozzles have been released to the general public and have been of immediate benefit. Data obtained on cultural control methods and ecological studies strengthened the accumulated information on which recommendations to growers are based. Such information has been valuable in developing cultural practices that are effective in reducing pink bollworm populations. The use of light traps to detect infestations has aided in the current eradication program in Arizona. Studies on effects of the pink bollworm on cotton quality will aid in determining the importance of the insect; also, with the increasing attention being given to high lint quality, the information obtained is becoming more important.

The general public can expect long term benefit from basic studies of the insect's biology. A resistant variety would be of great economic importance. Also, the use of parasites and diseases would be economical and would help meet the problems resulting from insecticide residues and resistance to insecticides.

Much of the data obtained will be useful in continued research on such problems as (1) finding new insecticides, (2) studies of irradiation to determine possibilities of using the sterile male method of control, (3) developing more effective light traps for surveys and for use as a research tool, and (4) physiological and other laboratory studies to develop a reservoir of fundamental knowledge for the purpose of gaining a better understanding of the insect and to aid in obtaining and interpreting data from field experiments.

5. WORK PLANNED FOR NEXT YEAR

The Texas Agricultural Experiment Station will continue work along the same lines during next year as in 1959.

The Arkansas Agricultural Experiment Station will terminate work on timing of insecticide applications in hill land, having obtained data on the subject for 9 years, but greater emphasis will be placed on the problem in (a) more fertile creek and river bottoms in western Arkansas, and (b) Delta and terrace soil areas of moderate productivity.

The Agricultural Engineering Research Division will continue work with light traps to determine characteristics of the optimum radiation source for use as an attractant in electric survey traps; factors affecting the design, installation, and operation of currently used survey traps. Work will be done on an improved portable power supply and on a simple ultraviolet meter for use in determining when survey trap lamp replacements are needed.

The Entomology Research Division will continue work on seven current line projects:

(1) Laboratory and field testing of new insecticides; testing soil fumigants against overwintering larvae; studies on mode of action of insecticides, insect resistance to insecticides, and possible use of anti-metabolites to destroy reproductive capacity of the insect.

(2) Introduced parasites will be reared for study of their life history and habits and for release in efforts to establish them in this country. Pathogens will be screened for effectiveness against the pink bollworm. Studies of environmental factors influencing invasion, multiplication, pathogenicity, etc., will be made.

(3) The cultural control studies will be continued at all locations except at Mount Pleasant and Lubbock, Tex. In cooperation with the Agricultural Engineering Research Division, further studies at the cotton gin will be made to evaluate low density flat-bale pressing for killing pink bollworms and to determine the velocity and density at which cottonseed may be conveyed in the blow systems and obtain 100% larval mortality. Also, in cooperation with the Texas Agricultural Experiment Station, various commercial stalk shredders

will be evaluated for their effectiveness in killing pink bollworms. The studies on factors affecting light trap efficiency and the range of attraction by the lights will be continued in cooperation with the Agricultural Engineering Research Division.

(4) New cotton varieties developed by plant breeders will be studied to determine any plant characteristics affording resistance to pink bollworm attack as compared with established commercial varieties. Suspected new hosts will be grown in the nursery at Brownsville and observed for pink bollworm attack.

(5) New studies of the seasonal activity of overwintering larvae in relation to temperature and soil moisture will be initiated at Waco, Tex. Laboratory studies of cold tolerance will be continued and also studies of the progressive winter mortality of larvae in several environments will be made at Waco and at Chickasha, Okla. Studies on diapause will be continued under controlled and natural conditions at Brownsville. Light traps will be used in connection with studies of field populations.

(6) Work will be continued on irradiation of various stages of the insect, mass-rearing methods to reduce or eliminate cannibalism and mold contamination, metabolic studies, and physiological effects of certain terrestrial factors and higher temperatures.

(7) The line project on effects of pink bollworm on the quality of cotton lint and seed will be terminated, but some further data on the problem will be obtained through the evaluation of insecticides for control of the insect.

7. PUBLICATIONS ISSUED OR MANUSCRIPTS PREPARED DURING THE YEAR:

Texas Agricultural Experiment Station:

Adkisson, Perry L. 1959. Effects of various humidities on the percentage hatch of pink bollworm eggs. (Accepted Jour. Kans. Ent. Soc.).

Adkisson, Perry L., L. H. Wilkes, and B. J. Cochran. 1959. Relative efficiencies of certain spray nozzles for cotton insect control. Jour. Econ. Ent. 52(4):985-91.

Adkisson, Perry L., L. H. Wilkes, and B. J. Cochran. Stalk destruction as a method for controlling the pink bollworm, Pectinophora gossypiella (Saund.). (In Press).

Brazzel, J. R. and J. C. Gaines. 1959. The toxicity of several insecticides to the eggs and larvae of the pink bollworm. Jour. Econ. Ent. 52(2):301-3.

Brazzel, J. R. and D. F. Martin. 1959. Winter survival and time of emergence of diapausing pink bollworms in Central Texas. Jour. Econ. Ent. 52(2):305-8.

Brazzel, J. R. and D. F. Martin. 1959. Pink bollworm resistance in cotton. Jour. Econ. Ent. 52(3):385-90.

Magee, W. J. and M. G. Davenport. 1959. The effect of spray nozzle arrangement and gallonage on control of the pink bollworm and other cotton insects. Jour. Econ. Ent. 52(3):466-7.

Wilkes, L. H., P. L. Adkisson, and B. J. Cochran. 1959. Effect of spray nozzle types on cotton insect control. Tex. Agric. Exp. Sta. Prog. Rpt. 2078.

Wilkes, L. H., P. L. Adkisson, and B. J. Cochran. 1959. Stalk shredder tests for pink bollworm control. Tex. Agric. Exp. Sta. Prog. Rpt. 2095.

Entomology Research Division, ARS, USDA:

Chapman, A. J., L. W. Noble, O. T. Robertson, and L. C. Fife. Survival of the pink bollworm under various cultural and climatic conditions. USDA Production Research Rpt. (In Press).

Chapman, A. J., O. T. Robertson, and L. W. Noble. Evaluation of stalk shredders and cutters for pink bollworm control. (In Preparation).

Clark, E. W. A comparative study of the free amino acids and carbohydrates of Pectinophora gossypiella (Saund.). Annals Ent. Soc. of Amer. (In Press).

Clark, E. W. A comparative study of the weights, and lipid and water content of larval and pupal pink bollworm (Pectinophora gossypiella (Saund.). (In Preparation).

Clark, E. W., A. L. Williamson, and C. A. Richmond. A collecting technique for pink bollworm and other insects using a Berlese funnel with an improved heater. Jour. Econ. Ent. 52(5):1010-12.

Clark, E. W., and D. S. Chadbourne. The haemocyte picture of larval and pupal pink bollworm (Pectinophora gossypiella (Saund.)). (In Preparation).

Glick, P. A., and L. W. Noble. A further study of airborne movement of the pink bollworm and other insects. (In Preparation).

Lowry, W. L., R. L. McGarr, and A. J. Chapman. Field tests with insecticides for pink bollworm control in 1958. (Prepared for reading at ESA Southwest Branch Meeting).

Lukefahr, M. J. Factors inducing diapause in pink bollworm larvae. (In Preparation).

Lukefahr, M. J., and J. A. Griffin. Life history of the pink bollworm at Brownsville, Texas, with special reference to effects of square and boll age on larval development. (In Preparation).

Lukefahr, Maurice J., and Claude Rhyne. Effects of nectariless cotton on populations of three lepidopterous insects. Jour. Econ. Ent. (In Press).

Richmond, C. A., and E. W. Clark. The effect of soil moisture and soil types on the nondiapause pink bollworm larvae. Read at Southwest Branch ESA Meeting. (Being Prepared for Publication).

Robertson, O. T., V. L. Stedronsky, and D. H. Currie. Kill of pink bollworms in the cotton gin and the oil mill. USDA Production Research Rpt. No. 26, 1959.

Shiller, Ivan. Host plants of the pink bollworm. (In Preparation).

Tsao, C. H., and G. T. Bottger. Laboratory studies on the effectiveness of Chipman R-6199 against some cotton insects. Jour. Econ. Ent. (In Press).

Agricultural Engineering Research Division, ARS, USDA:

Hollingsworth, J. P., and C. P. Briggs. A transistorized power supply and automatic control unit for operation of survey type electric insect traps. (To be Published in ARS Series).

8. APPROVED:

/S/ Dial F. Martin	/S/ R. D. Lewis
Chairman, Technical Committee	Regional Administrative Advisor